FORM PTO-1390 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE (REV 5-93)

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 9052-91

U S APPLICATION NO (If known, see 37 C F R 1 5): 09/937413

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB00/01159	October 5, 2000	March 29, 1999

TITLE OF INVENTION

CENTRE LINE MULTIDIMENSIONAL SUSPENSION SYSTEM

APPLICANT(S) FOR DO/EO/US

Steve Smith and Simon Sykes

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).

4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau). Courtesy Copy
   b. [ ] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).

6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [X] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.

8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98.

12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. [x] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.

14. [ ] A substitute specification.

15. [ ] A change of power of attorney and/or address letter.

16. [x] Other items or information: A copy of the International Preliminary Examination Report

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.50)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/937413	PCT/GB00/01159	9052-91

17. [X] The following fees are submitted:	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO **$860.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) **$690.00**		
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) **$710.00**		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$1,000.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT = $860.00	$ 860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	21-20 =	1	X $18.00	$ 18.00	
Independent Claims	1-3 =	0	X $80.00	$	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	

TOTAL OF ABOVE CALCULATIONS =	$	
Reduction by 1/2 for filing by small entity, if applicable. Applicant qualifies as Small Entity under 37 CFR 1.27.	$	
SUBTOTAL =	$ 878.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).	$	
TOTAL NATIONAL FEE =	$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +	$	
TOTAL FEES ENCLOSED =	$878.00	
	Amount to be refunded	$
	charged	$

a. [X] A check in the amount of **$878.00** to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-0220.

NOTE: **Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

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"Express Mail" mailing label number EL920740164US
Date of Deposit: September 25, 2001

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Box PCT, Commissioner for Patents, Washington, DC 20231.

Joyce Paoli
Date of Signature: September 25, 2001

James R. Cannon

35,839
REGISTRATION NUMBER

PTO FORM-1390 (REV 5-93)

Attorney's Docket No. 9052-91 PATENT

IN THE UNITED STATES DESIGNATED OFFICE (DO/US)

In re: Application of Steve Smith et al;
Serial No.: To be Assigned
Filed: Concurrently Herewith
For: *CENTRE LINE MULTIDIMENSIONAL SUSPENSION SYSTEM*
Date: September 25, 2001

BOX PCT
Commissioner for Patents
Washington, DC 20231

PRELIMINARY AMENDMENT

Sir:

Prior to the examination of the above application and calculation of claim fees, please amend the above-identified application as indicated below. Attached hereto at page 3 is a marked version of the changes made to the specification and claims by the current amendment. The marked version of the changes is captioned "**Version With Markings To Show Changes Made**".

In the Specification:

On page 1, line 1, please insert the following:

--Cross-Reference to Related Applications

The present application is a U.S. national phase application of PCT International Application No. PCT/GB00/01159, having an international filing date of March 28, 2000 and claiming priority to Great Britain Application Nos. 9907145.8 and 0001351.6 filed March 29, 1999 and January 21, 2000. The above PCT International Application was published in the English language and has International Publication No. WO 00/58660.--

In the Claims:

Please delete Claim 22.

REMARKS

Claims 1-21 are presented for examination and correspond to the substitute claims submitted during PCT examination. Various claims have been amended to better conform to U.S. practice. Applicants respectfully request substantive examination on the merits.

Respectfully submitted,

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Joyce Paoli
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PCT

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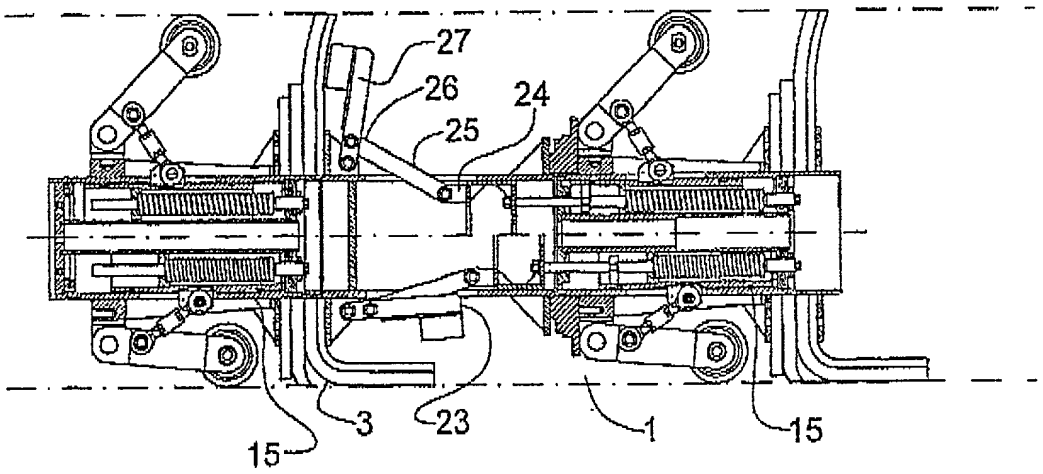

(57) Abstract

There is described a novel apparatus for use in connection with pipe cleaning and monitoring systems. The apparatus is a suspension system adapted to fit a pipeline pig shaft, the pig being provided with a plurality of wheels. The wheels are concentrically mounted around a biasing means which is operable in a direction coplanar with the pig shaft. There is also described a pipeline pig comprising the suspension system and a method of cleaning a pipeline.

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APPARATUS

This invention relates to a novel apparatus for use in connection with pipe cleansing and monitoring systems.

In particular the invention relates to a novel suspension system for use in relation to pipeline pigging apparatus, for pipes ranging in diameter from as small as 6 inches (15.24cm) to as large as 56 inches (142.24cm), although the system could fit into pipes of any diameter. The invention also relates to a pig comprising the suspension system and to a method of cleaning or monitoring a pipeline.

Both subsea and land pipelines for the transportation of various products are subjected to frequent internal cleaning and inspection. This process, known as "pigging", is effected by inserting a "pig" into the pipeline. The "pig" usually comprises a longitudinal shaft upon which is mounted at least one sealing disc and at least one guide disc, more normally a pair, comprising a sealing disc and a guide disc, is situated at each end of the shaft.

In a dewatering, RFO (ready for operations) or cleaning pig, the diameter of the sealing disc is such that it creates a positive interference between the inner walls of the pipe and the outer surface of the sealing disc. Motion is induced in the pig vehicle due to the flow of the product, e.g. oil or gas, in the pipeline against the sealing disc. Thus, the pig progresses along the pipeline, the sealing disc scraping the sides of the pipe wall causing a sealing, cleaning and scouring motion. Such pipeline pigs are used in commissioning and decommissioning fuel pipelines and cleaning pipelines in use, e.g. production pipelines.

Pipeline cleaning technology up to this point has relied upon a pig unit consisting of discs connected by spacer rings via their longitudinal axis. The weight of the pig is supported on "hard" guide discs or, alternatively, individually sprung wheels, whilst the cleaning is carried out by "soft" sealing discs.

Inspection pigs operate along similar lines, but because there is no necessity to scrape the internal walls of the pipe, other than to effect propulsion inspection pigs can be mounted on individually sprung wheels. They usually comprise a longitudinal shaft provided with one or more guide discs and are propelled in a similar fashion to a cleaning pig. An inspection pig will also be provided with monitoring equipment, for example, gauging discs, odometer wheels, or n.d.t. (non destructive testing) measuring equipment to enable the detection of structural flaws in the pipes. Such monitoring equipment is well known to those skilled in the art.

However, both types of pig currently used suffer from the disadvantage that they cannot be run concentrically down a pipeline. For cleaning pigs this can result in uneven wear of the guide and/or sealing discs. Even with a wheeled pig, because, *inter alia*, the wheels are independently sprung, the weight of the pig will usually rest on a fraction of the wheels at any given time, for example, when the pig is travelling through a horizontal pipe, the lowest set of wheels will take most of the load. This will cause the pig to run off centre and cause uneven wear on the discs.

To compensate for this "below centre line" running, up until now sealing discs have been manufactured with a considerable oversize on the outer diameter. This allows for off centre line running and wear and tear on the disc, but creates considerable friction between the sealing disc and pipe wall and results in a differential pressure that builds up across the sealing disc. This pressure differential is used effectively to 'drive' the pig, but when the friction is too great the differential pressure becomes unrealistically high. In fact, it can become so high that a phenomenon known as 'plugging' could occur.

Thus, there has long been a desire to produce a pig which reduces wear and friction thereby increasing efficiency and increasing the pig's life span. A reduction in friction between sealing discs and pipe wall would result in a lower differential pressure, across the sealing disc, by which method the pig is propelled along the pipe.

Moreover, there has been an increasing desire to manufacture a pig which is capable of being used in pipelines of varying diameters, such as, for example, that which is being laid as part of the large Åsgard transport line in the Norwegian Sea.

We have now surprisingly found a novel suspension unit which is suitable for use with a pig assembly and which overcomes or mitigates the aforementioned disadvantages. The suspension unit also permits the manufacture of a pig which is capable of functioning in multidiameter pipelines. Previously, it has only been possible to manufacture a pig which can adjust between say 40 and 42 inches (101.6cm and 106.68cm), whereas the novel suspension systems permit variation between, for example, 28 and 42 inches (71.12cm and 106.68cm), as well as 10 and 16 inches (25.4cm and 40.64cm) and other combinations of dual diameter pipeline that are commonly found in subsea and land applications.

Thus, according to the invention we provide a pig suspension system adapted to fit a pig shaft and comprising a plurality of wheels characterised in that the wheels are concentrically mounted around a biassing means which is operable in a direction coplanar with the pig shaft.

The biassing means is preferentially a piston. The piston used in the suspension unit of the invention may comprise any conventionally known type of piston, such as a hydraulic piston. However, a preferred piston is a spring loaded piston.

The wheel and piston arrangement will preferably comprise a plurality of wheels wherein each wheel is supported by a radially mounted suspension arm which itself is connected to a piston mounting block by a pivot pin. The suspension arm is pivotally connected to a tie rod. The end of the tie rod distal to the suspension arm being connected via a pivot pin to the piston. The piston assembly is such that the piston operates in a direction coplanar with the pig shaft. Thus in operation the piston will generally be acting in, for example, a horizontal plane and the tie rod will convert the

piston movement to radial movement of the suspension arm and consequently the wheel.

The piston may be internally or externally mounted.

Thus, according to the invention we provide a pig suspension system adapted to fit a pig shaft and comprising a pig body provided with a plurality of wheels characterised in that the wheels are concentrically mounted around a biassing means which is operable in a direction coplanar with the pig shaft and each wheel being connected to a suspension arm, each suspension arm being operably linked to an externally mounted biassing means.

As previously mentioned, one significant advantage of the suspension unit of the invention is that it provides centre line running of the pig. Centre line running is achieved because there is effectively a constant loading on each individual wheel, of which the sum total load from all wheels is greater than the weight of the pig, thereby centralising it in the pipe. With a conventionally sprung wheel, the loading can increase significantly if the diameter of the pipe reduces and will usually lead to failure of the wheel bearings, roller covering, etc.. However, with our novel suspension unit comprising a spring loaded piston, in conjunction with suspension arm geometry, the spring compresses giving an increase in force, but controlled load of the wheel. Thus it is a particular aspect of this invention which provides a pig suspension unit which has substantially constant wheel loading. In an especially preferred embodiment we provide a suspension unit in which the wheel loading can be kept between the limits of 400N and 13,000 N. Thus, for example, the wheel loading in a 28 inch (71.12cm) diameter pipe will be between 4,000 and 7,000 N; for a 42 inch (106.68cm) diameter pipe the wheel loading will be between 6,000 and 10,000 N.

For a 10 inch (25.4cm) diameter pipe the wheel loading will be 400N to 1,500N: for a 16 inch (40.64cm) diameter pipe the wheel loading will be 500N to 2000N.

The wheel loading can be varied depending upon, inter alia, the nature and tuning of the suspension system. Thus, in the case of a spring loaded piston, the spring rate may be varied depending on each application. If the weight of the pig changes, through, for example adding parts, then the springs can be tuned which will modify the spring rate. Thus, by way of example only, the spring rate may be between 10 and 70 N/mm, preferably between 20 and 60 N/mm. Furthermore, the wheel loading can be altered if the spring is adjusted. The spring pre-loading is a spring rate of 50N/mm and 27.5mm pre-loading and may be between 20 and 50 mm in the case of the 28 to 42 inch (71.12cm to 106.68cm) system. A preferred arrangement will be variable depending upon application.

The suspension can be tuned by adjusting the position of the tie rod pivot point on the suspension arm. Thus the pivot point may be varied depending upon, *inter alia*, the pig weight and the performance required of the pig and which would be understood by one skilled in the art. The geometry of the tie rod connection to the suspension arm will also vary depending upon the application, although it is related to the spring rate. For example, there will be a maximum continuous wheel loading for a chosen wheel and the geometry will be "balanced" by adjustment of the spring rate.

In a further preferred embodiment, the suspension arms of the wheel assembly is offset from the axis of the pig shaft. This enables the wheel assembly, and hence the pig, to rotate whilst travelling down a pipe. This has the advantage that there is an evening out of the length of time any wheel experiences maximum load and, more importantly, it minimises and evens out the wear on the sealing discs. The degree of offset may be varied depending upon the application of the pig, but, for example, the suspension unit may be offset between 1 and 3° of the pig shaft axis and preferably 2° of the pig shaft axis.

The number of wheels provided in a suspension unit of the invention may vary depending upon the size and weight of the pig. In a preferred embodiment a pig will be provided with at least two wheel assemblies comprising the suspension unit of the invention, e.g. a front and a rear set. Although, for articulated pigs more than two sets may be used. Although each set may comprise any number of wheels, preferably supported by up to eight wheels may be used in any set, although this number may be varied according to the dimensions of the pig. All the wheels in a single assembly are preferably connected to an appropriate piston although it is within the scope of the invention that some of the wheels may be conventionally mounted. The wheels are generally arranged so that any wheel is mounted with another wheel on the opposing side of the shaft. Alternatively, if an odd number of wheels is used then the wheels may be arranged asymmetrically.

However, in a preferred embodiment a pig is provided with two sets of wheels, substantially one at either end of a pig shaft. We have found it particularly advantageous when operating a pig with at least two wheel assemblies to have the wheels of one assembly offset from the plane in which the wheels of a second assembly operate. By the term wheel it is intended to encompass conventionally known wheels, rollers, spheres, etc. and other known alternatives.

The tie rod used in the suspension system of the invention may incorporate a turnbuckle. The turnbuckles may be provided separately to the suspension. However, as an aspect of the invention we provide a turnbuckle for use in connection with a tie rod and a suspension system as herein before described.

According to a further feature of the invention we provide a pipeline pig comprising a suspension unit as hereinbefore described.

The novel wheeled pig is advantageous in that, *inter alia*, in all spheres of operation it retains the centre line, unlike conventionally known pigs. Thus, as a consequence, it reduces and evens out the wear on the discs and increases efficiency. Thus, in one

aspect of the invention, conventionally used discs may be included in the pig system. Such discs usually comprise substantially circular polyurethane discs, "hard" discs being used to support the pig and "soft" discs to scrape the inner surface of the pipe. However, for use in relation to dual diameter pipes, a collapsible disc may advantageously be used, such that the disc may, for example, fold or unfold to reflect the dimensions of the pipe.

The efficiency of a dewatering pig may be measured in a variety of ways. A dewatering pig may be used in conjunction with a hygroscopic material, such as a glycol, e.g. ethylene glycol, the glycol often being entrapped as a "plug" between the discs. Thus one way of measuring the efficiency of a dewatering pig is to measure the water uptake of the glycol. Generally, the lower the efficiency, e.g. due to wear on the discs and eccentricity, the greater the water uptake of the glycol. Conventionally, a dewatering pig comprises a train of, e.g. six, pigs together. Normally, glycol is entrapped between pigs 1 and 2 (glycol 1); 2 and 3 (glycol 2); and 3 and 4 (glycol 3); glycol 1 taking up the most water. A typical example of the water content of the glycol following a dewatering run is;

glycol 1 : 30% w/w water

glycol 2 : 5% w/w water

glycol 3 : 1% w/w water

The determination of water content may be carried out using conventional techniques known *per se*, e.g. Karl Fischer titration.

However, by the use of the suspension system of the present invention the efficiency may be improved. Thus, for a train of six pigs using the suspension system of the invention, the glycol is found to have a water content of;

glycol 1 : 5% w/w water

glycol 2 : 2% w/w water

glycol 3 : 0.5% w/w water

We especially provide a pipeline pig with a dewatering efficiency of between 0.1 and 1.0% w/w water in glycol, preferably 0.2 to 0.8% w/w and more preferably 0.4 to 0.6% w/w, eg 0.5%w/w.

It is an especially advantageous feature of the present invention that a pipeline pig using a centre line suspension system can operate at a minimal differential pressure and high efficiency.

Thus according to a further feature of the invention we provide a pipeline pig as hereinbefore described which has a dewatering efficiency of 0.5% w/w or less water in glycol and a differential pressure of 0.5 bar or less.

The differential pressure is preferably between 0.2 and 0.5 bar, more preferably between 0.2 and 0.4 bar, e.g. 0.3 bar.

It is well understood in the art that if a pipeline pig should stall inside a pipeline that increased pressure may be applied in the direction of flow in order to restart movement of the pig.

The pressure applied can be high and it is essential that the sealing disc of the pig be designed so that the increased pressure will not cause it to "flip" forward and create bypass of the driving medium, resulting in complete loss of driving force.

The pressure at which the sealing disc commences to flip is known as the "flip pressure". The flip pressure, for those versed in the art, is normally stated to be a multiple of the differential pressure. For example a flip pressure of 10 times is common.

It is a feature of this invention that when comparing it to conventional high interference/high differential pressure pig designs, a much higher multiple of flip pressure to differential pressure can be achieved.

This results in the benefit of either the sealing disc being able to withstand a higher flip ratio multiple (thereby reducing the likelihood of flipping and stalling) and/or the ability for the drive disc to be of lighter construction as the quoted example of the times 10 multiplier will result in a lower absolute flip pressure value which, in a multi-diameter pipeline application, will give it the ability to fold more easily when entering the lesser diameter.

Thus according to a yet further feature of the invention we provide a pipeline pig as hereinbefore described which has a flip pressure of 5 bar or less.

The flip pressure is preferably between 2 and 5 bar, more preferably between 2 and 4 bar, e.g. 3 bar.

In a further embodiment of the invention two or more pigs may be coupled together. Such a coupled pig is advantageous in that, *inter alia*, it aids in progression of the pig over any voids in the pipeline. The pigs may be coupled in any conventional manner, e.g. by a ball joint and shaft, enabling one pig to be rotatable relative to the other.

According to a further feature of the invention we provide a method of cleaning a pipeline which comprises passing a pig as hereinbefore described down the pipeline, at least once.

According to the invention we also provide a method of detecting a defect in a pipeline which comprises a measuring pig as hereinbefore described down the pipeline, at least once.

Optionally a pig of the invention may be adapted so as to act as a cleaning pig and a measuring pig simultaneously.

In a further alternative embodiment, the pig of the invention may be provided with conventional detector systems, for example gauging discs, odometer wheels, thus enabling the pig to be used as a detector pig and enabling the manufacture of semi-intelligent cleaning pigs.

The invention will now be illustrated by way of two examples only and with reference to the accompanying drawings, but in which the principal of the invention would remain the same for all pipe diameters.

Figure A illustrates centreline suspension geometry; for a 28 to 42 inches (71.12cm to 106.68cm) suspension

Figure B illustrates the suspension geometry for varying positions including nominal running positions for 42 inch (106.68cm) and 28 inch (71.12cm);

Figure C is a graph of wheel load versus suspension arm deflection, for a 28 inch to 42 inch (71.12cm) to (106.68cm) suspension system; and

Figure D is a graph of wheel load versus suspension arm deflection, for a 10 to 16 inch (25.4cm to 40.64cm) suspension system.

Figure 1 is a cross section along the vertical axis A - A of the suspension unit shown in Fig 2;

Figure 2 is an end view of the suspension unit according to the invention;

Figure 3 is a cross-section of a pig provided with two wheel assemblies each comprising a suspension unit of the invention;

Figure 4 is a cross section of the suspension unit provided with engaging means between the disc and the piston arrangement;

Figure 5 is a cross section of a hollow suspension unit of a pig;

Figure 6 is a cross section of an alternative wheel and piston arrangement of a hollow suspension unit; and

Figure 7 is a schematic representation of a train of pigs in a pipeline.

With reference to Figure 1, a wheel assembly (5) comprises a wheel (9) rotatably mounted on a suspension arm (10). The suspension arm (10) being pivotally

mounted to the body mounting block (11). The suspension arm (10) is also provided with a tie rod (12), which tie rod (12) is provided with a turnbuckle (12a) and is pivotally connected at one end (13) to the suspension arm (10) and at the other end (14) to the piston mounting block (11a). The end (14) of the tie rod (12) is slidably connected to the housing via a piston assembly (15) comprises a spring (16) mounted on a piston shaft (17), the spring (16) resting on a fixed bulk head (18) of the piston chamber (19) and biased against the other slidable bulk head (20) of the chamber (19).

Referring to Figure 2, a plurality of radially positioned wheels (9) are each rotatably held by a suspension arm (10), the suspension arm (10) being connected to a piston (17) by a tie rod (12).

With reference to Figure 3 a pipeline cleaning pig (1) comprises a longitudinal shaft (2), radially mounted cleaning discs (3 and 4) and wheel assemblies (5 and 6) at the forward end (7) and distal end (8) of the shaft (2).

With reference to Figure 4, the piston assembly (15) of a pipeline cleaning pig (1) is provided with means (23) enabling the piston (15) to engage with the disc (3). The disc engaging means (23) comprises a push rod (24) attached to the piston (15), the push rod (24) being pivotally connected to an arm, (25). The distal end (26) of the arm (25) is provided with a disc engaging plate (27). The disc engaging plate (27) may optionally be pivotally mounted on the arm (25)

With reference to Figures 5 and 6, a wheel assembly (5) comprises a wheel (9) rotatably mounted on a suspension arm (10). The suspension arm (10) being pivotally mounted to the body mounting block (11). The suspension arm (10) is also provided with a tie rod (12), which tie rod (12) is provided with a turnbuckle (12a) and is pivotally connected at one end (13) to the suspension arm (10) and at the other end (14) to the piston mounting block (11a). The end (14) of the tie rod (12) and the piston mounting is slidably connected to the housing via a piston assembly (15)

comprising a spring (16) mounted in a piston housing, the spring (16) rests on a fixed bulk head (18) of the piston housing and biased against the other slidable bulk head (20) of the piston housing which also forms part of the piston mounting block (11a). The piston housing (19) being situated on an inner surface Figure 5/outer surface Figure 6 (21) of the pig body (22).

In operation the piston biases the tie rod and thus the wheel to fit snugly against the wall of a circular cross section pipe.

With reference to Figure 6, a series of pigs are passed down a pipeline in a train. Generally, the space between the four leading pigs is providing with a dewatereing agent, such as glycol, whilst the space between the three trailing pigs is provided with air. The glycol takes up any water that passes the first sealing disc and so on, so that by the time any water reaches the last glycol plug the water uptake is minimised.

Example 1

Suspension Geometry and Force Calculations for a typical 28 to 42 inch (71.12cm to 106.68cm) system.

Figure A illustrates Centreline Suspension Geometry

Note: Point B is constrained to move horizontally by the inner piston assembly, whilst the arm pivots about point O.

W=force at wheel(s)	a=Effective link length 75.8765mm
R=load in turn-buckle	1=overall arm length
F=Spring (piston force)	ϕ=angle between turnbuckle and piston CL
Qh=Hor. force on mounting	θ=angle between pivot to body mounting block CL
Qv=Vert. force on mounting	ψ=Angle between arm CL and piston CL

α=Difference between θ and ψ; constant = 8.7175°

Take moments about position O for link AO

$W*1*Cos\psi=R*a*Sin(\theta+\phi)a)$

but resolving R horizontally at B we get

$R*Cos\phi = F$ b)

or

$R = F/Cos\phi$ c)

substitute c) into a)

$W*1*Cos\psi= F/Cos\phi\ aSin(\theta+\phi)$

rearranging gives

$W = F*a*Sin(\theta+\phi)/Cos\psi/Cos\phi$ d)

Simplifying gives

$W = F*k$ where $k = Sin(\theta+\phi)/1/Cos\psi/Cos\phi$ e)

Referring to Table 2 below and calculating k we get NB $\theta = \psi - 8.7175°$

Table 1

Suspension geometry and force calculations for a typical 28 inch to 42 inch (71.12cm to 106.68cm) system

Position	y	q	f	k	Dia over Wheels	x (mm)		W (N)				
	a	8.7175					l N/mm	40	50	60	50	50
							p mm	33.2	26.6	22.2	27.5	40.0
1	47.0182	38.3007	58.5278	0.7559		-5.00	# ####	6832	6529	6227	6803	10581
2	45.0000	36.2823	57.1409	0.7051	1016mm (42")	0.00		7500	7500	7500	7356	14281
3	37.2031	28.4856	51.9249	0.5440		17.76		8878	9651	10424	9848	18508
4	30.0709	21.3534	47.3345	0.4304		31.80		8959	10054	11149	10210	19362
5	23.4220	14.7045	43.2047	0.3432		42.97		8371	9551	10731	9675	18282
6	17.0933	8.3758	39.4099	0.2718		51.86		7401	8529	9656	8627	16356
7	10.9736	2.2561	35.8724	0.1706		58.83		5025	5828	6631	5890	11174
8	4.9787	-3.7388	32.5403	0.1555	668mm (28")	64.12		4843	5641	6438	5697	10774
9	1.9034	-6.8141	30.8851	0.1289		66.25		4103	4786	5469	4832	9187
10	-1.1669	-9.8844	29.2709	0.1031		67.99		3341	3902	4463	3939	7498

Position	y	q	f	k	Dia over Wheels	x (mm)	0 0	W(N)	F(N)	R(N)	Qy(N)	Q(N)
	a	8.7175					l N/mm	50	50	50	50	50
							p mm	27.5	27.5	27.5	27.5	27.5
1	47.0182	38.3007	58.5278	0.7559	0.000	-5.00		6803	9000	17239	7899	11975
2	45.0000	36.2825	57.1409	0.7051	1016mm (42")	0.00		7756	11000	20274	9274	14388
3	37.2031	28.4856	51.9249	0.5440	0.000	17.76		9848	18104	29357	13261	22441
4	30.0709	21.3534	47.3345	0.4304	0.000	31.80		10210	23720	35000	15526	28350
5	23.4220	14.7045	43.2047	0.3432	0.000	42.97		9675	28188	38671	16799	32814
6	17.0933	8.3758	39.4099	0.2718	0.000	51.86		8627	31744	41086	17457	36227
7	10.9736	2.2561	35.8724	0.1706	0.000	58.83		5890	34532	42615	19082	39453
8	4.9787	-3.7388	32.5403	0.1555	668mm (28")	64.12		5697	36648	43473	17687	40693
9	1.9034	-6.8141	30.8851	0.1289	0.000	66.25		4832	37500	43696	17598	41424
10	-1.1669	-9.8844	29.2709	0.1031	0.000	67.99		3939	38196	43787	17470	42001

Similarly, by reference to Table 2 below we can calculate the wheel loads with respect to the suspension geometry that is found to be an extension of a 10 to 16 inch (25.4cm to 40.64cm) system.

For each particular range of pipe sizes the calculations remain the same but the values will differ.

The 28 to 42 inch (71.12cm to 106.68cm) and 10 to 16 inch (25.4cm to 40.64cm) calculations are given as examples only.

Table 2

k for varying suspension positions on a typical 10 inch to 16 inch (25.4cm to 40.64cm) system

Position	y	q	f	k	Dia over Wheels	x (mm)		W (N)				
	a	0					l N/mm	35	70	60	50	50
							p mm	20.0	20.0	2.4	27.5	40.0
1	43.9900	43.9900	65.3800	1.0989		0.00		769	1538	1266	12088	17582
2	38.4400	38.4400	59.4100	0.8677	(16")	8.08		853	1706	4365	12349	16687
3	33.2900	33.2900	54.3400	0.7158		14.62		867	1735	5848	12060	15639
4	28.4300	28.4300	49.8400	0.6027		20.07		845	1691	6501	11469	14782
5	23.7800	23.7800	45.7200	0.5118		24.68		800	1601	6653	10683	13741
6	19.3000	19.3000	41.8800	0.4353		28.60		740	1481	6477	9768	12718
7	14.9300	14.9300	38.2700	0.3685		31.93		670	1340	6073	8760	11703
8	10.6500	10.6500	34.8200	0.3085		34.74		591	1182	5499	7680	10727
9	6.4200	6.4200	31.5100	0.2533	(10")	37.07		506	1012	4769	6512	9009
10	2.2400	2.2400	28.3200	0.2018		38.96		416	833	4006	5365	7523

Position	y	q	f	k	Dia over Wheels	x (mm)	0 0	W(N)	F(N)	R(N)	Qv(N)	Q(N)
	a	0					l N/mm	70	70	70	70	70
							p mm	20.0	20.0	20.0	20.0	20.0
1	43.9900	43.9900	65.3800	1.0989		0.00		1538	1400	3361	-1517	2064
2	38.4400	38.4400	59.4100	0.8677	(16")	8.08		1706	1966	3863	-1619	2547
3	33.2900	33.2900	54.3400	0.7158		14.62		1735	2423	4157	-1355	2928
4	28.4300	28.4300	49.8400	0.6027		20.07		1691	2805	4349	-1633	3246
5	23.7800	23.7800	45.7200	0.5118		24.68		1601	3128	4480	-1606	3516
6	19.3000	19.3000	41.8800	0.4353		28.60		1481	3402	4569	-1569	3747
7	14.9300	14.9300	38.2700	0.3685		31.93		1340	3635	4630	-1528	3943
8	10.6500	10.6500	34.8200	0.3085		34.74		1182	3832	4668	-1483	4109
9	6.4200	6.4200	31.5100	0.2533	(10")	37.07		1012	3995	4686	-1437	4246
10	2.2400	2.2400	28.3200	0.2018		38.96		833	4127	4688	-1391	4355

Of the above options only the 50 N/mm spring is suitable to fit within the space constraints of the pig body. With this rate the weight 7,500N of a section will be adequately supported at 42 inches (106.68cm) but only 72% supported at 28 inches (71.12cm). However the actual weight of the vehicle is now know to be a total of 1,00-kg or 5,000N per module so the configuration is adequate even at 28 inches (71.12cm). Rather than operate with near maximum spring pre-load, 27.5mm was chosen as giving a better match to support the actual vehicle weight. The final column shows the effect on wheel loading if the springs are adjusted to their maximum pre-load setting of 40 mm. Figure C shows the data from the Table 1 in graphical form.

Example 2

Suspension Modules Material Selection for a typical 28 to 42 inch (71.12cm to 106.68cm) suspension system.

The Main Body of The Modules.

The material selected for the main body of the suspension modules is a drawn over mandrel (DOB) cylinder tube ref. ASTM A513 grade 1026. The drawn tube has a tensile strength figure of 585 N/mm^2. The other components fabricated onto the body are BS970:080M50 (EN43A).

The finished body is phosphated all over and the external surfaces are xylan 1070 coated.

The Piston.

The material selected for the piston is BS970:080M50. The piston comprises a main tube and a welded in flange of the same material. The finished piston is phosphated and xylan 1070 coated.

The Suspension Linkage Mechanism.

The majority of the suspension linkage components are manufactured from BS970:708M40 which is heat treated to condition R. This gives a tensile strength 700/850 N/mm^2 and a hardness value of 201/255 HB. The components that are not manufactured from this material are the suspension arms due to the requirement to be able to have simple fabrication done, are manufactured from BS970:080M40 (EN8). All suspension linkage components are phosphated and xylan 1070 coated.

Suspension Springs.

The spring rate and overall working parameters were passed on to our chosen spring manufacturer.

Discussion indicated that the springs should be manufactured from BS1429:735A50 which is hardened and tempered to 48/50 HRC.

Following heat treatment the springs are shot peened and zinc plated and passivated.

Wheel Assembly.

The wheel assembly components are manufactured form stainless steel AISI No 303 (hub) and 316 (rest).

Stainless 303 was chosen for being non-magnetic when used in an inspection vehicle environment whereas 316 was chosen for its extra resistance to sea water.

The tyre material is a polyurethane which has a hardness rating of 92-95 Shore A.

The bearing elements are sealed units and a rotating labyrinth seal in stainless steel ref 1.4310 is positioned in two places.

Claims

1. A pig suspension system adapted to fit a pig shaft and comprising a plurality of wheels characterised in that the wheels are concentrically mounted around a biasing means which is operable in a direction coplanar with the pig shaft.

2. A pig suspension unit according to claim 1 characterised in that the biasing means is a piston.

3. A pig suspension system according to claim 1 characterised in that the piston is a spring loaded piston.

4. A pig suspension system according to claim 1 characterised in that each wheel is supported by a radially mounted suspension arm, the suspension arm being provided with a pivot pin connected to a suspension mounting.

5. A pig suspension system according to claim 4 characterised in that the suspension arm is connected at a point along its length to a tie rod, the tie rod being connected via a pivot pin to a sliding piston assembly.

6. A pig suspension system according to claim 1 characterised in that it provides substantially constant wheel loading.

7. A pig suspension unit according to claim 1 characterised in that the biasing means is internally mounted.

8. A pig suspension system adapted to fit a pig shaft and comprising a pig body provided with a plurality of wheels characterised in that the wheels are concentrically mounted around a biasing means which is operable in a direction coplanar with the pig shaft and each wheel being connected to a

suspension arm, each suspension arm being operably linked to an externally mounted biasing means.

9. A pig suspension system according to claim 8 characterised in that the pig is an inspection pig.

10. A pig suspension system according to claim 1 characterised in that the suspension arms of the wheel assembly are offset from the axis of the pig shaft.

11. A pig suspension system according to claim 10 characterised in that the suspension arms are offset by between 1 and 3° of the pig shaft axis.

12. A pig suspension system according to claim 11 characterised in that the suspension arms are offset by 2° of the pig shaft axis.

13. A suspension system according to claim 1 characterised in that the biasing means is also provided with a disc engaging means.

14. A pipeline pig comprising a suspension system according to claim 1.

15. A pipeline pig comprising a suspension system according to claim 8.

16. A pipeline pig provided with at least one sealing disc and at least one guide disc and a centre line suspension system, which pig has a high dewatering efficiency.

17. A pipeline according to claim 16 characterised in that the pig has a differential pressure of 0.5 bar or less.

18. A pipeline pig according to claims 14, 15 or 16 provided with at least two wheel assemblies.

19. A pipeline pig according to claim 18 characterised in that the wheels of one wheel assembly are offset from the plane in which the wheels of a second assembly operate.

20. A pipeline pig according to claims 14 or 16 adapted to be a monitoring pig.

21. A pipeline pig provided with at least one sealing disc and at least one guide disc, and a centre line suspension system, which pig has a flip pressure of 5 bar or less.

22. A pig suspension system according to claim 1 characterised in that the sealing disc is of a collapsible nature enabling the pig to be used in multidimensional pipes.

23. A method of cleaning a pipeline which comprises passing a pig according to claims 14, 16 or 21 down the pipeline.

24. A method of detecting a defect in a pipeline which comprises passing a pig according to either of claims 15 or 20 down the pipeline.

25. A pipeline pig comprising a suspension system according to claim 1 which is adapted to be a cleaning pig and is adapted to be a monitoring pig.

26. A turnbuckle for use in connection with a tie rod and a suspension system as herein before described.

27. A pipeline pig according to claims 14, 16 or 21 characterised in that the pig is coupled to at least one other pig.

28. A pig suspension system substantially as hereinbefore described with reference to the accompanying description and drawings.

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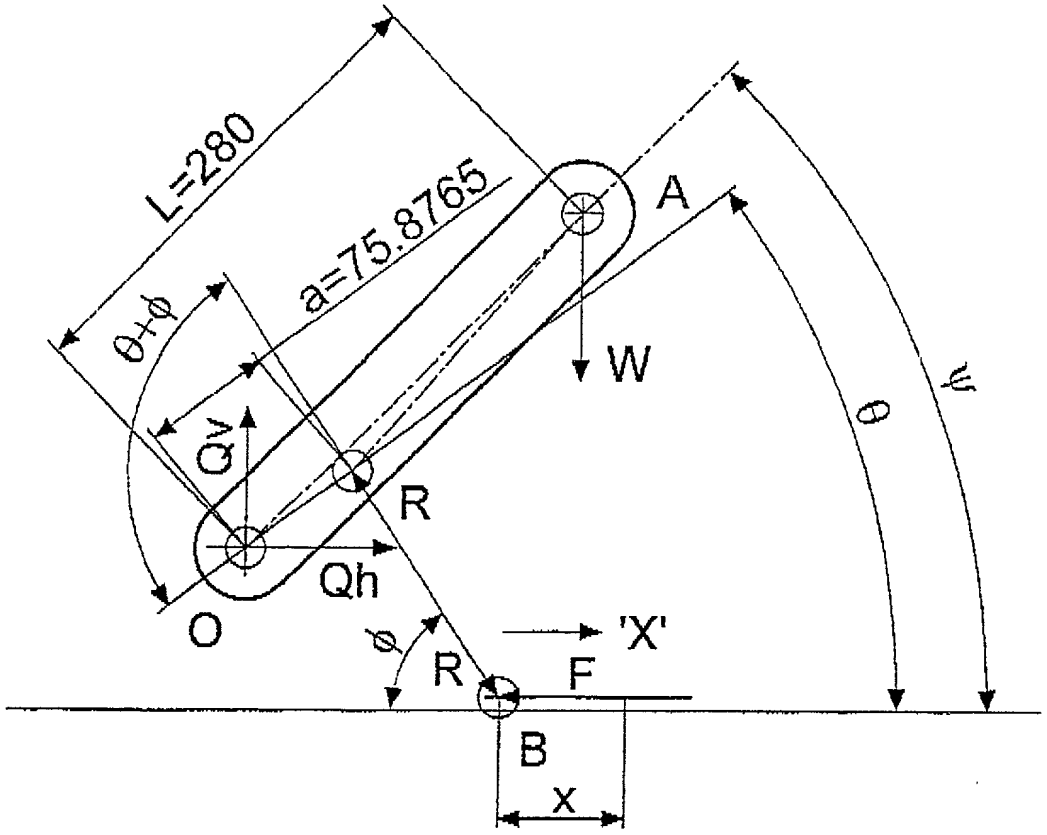

Fig. A

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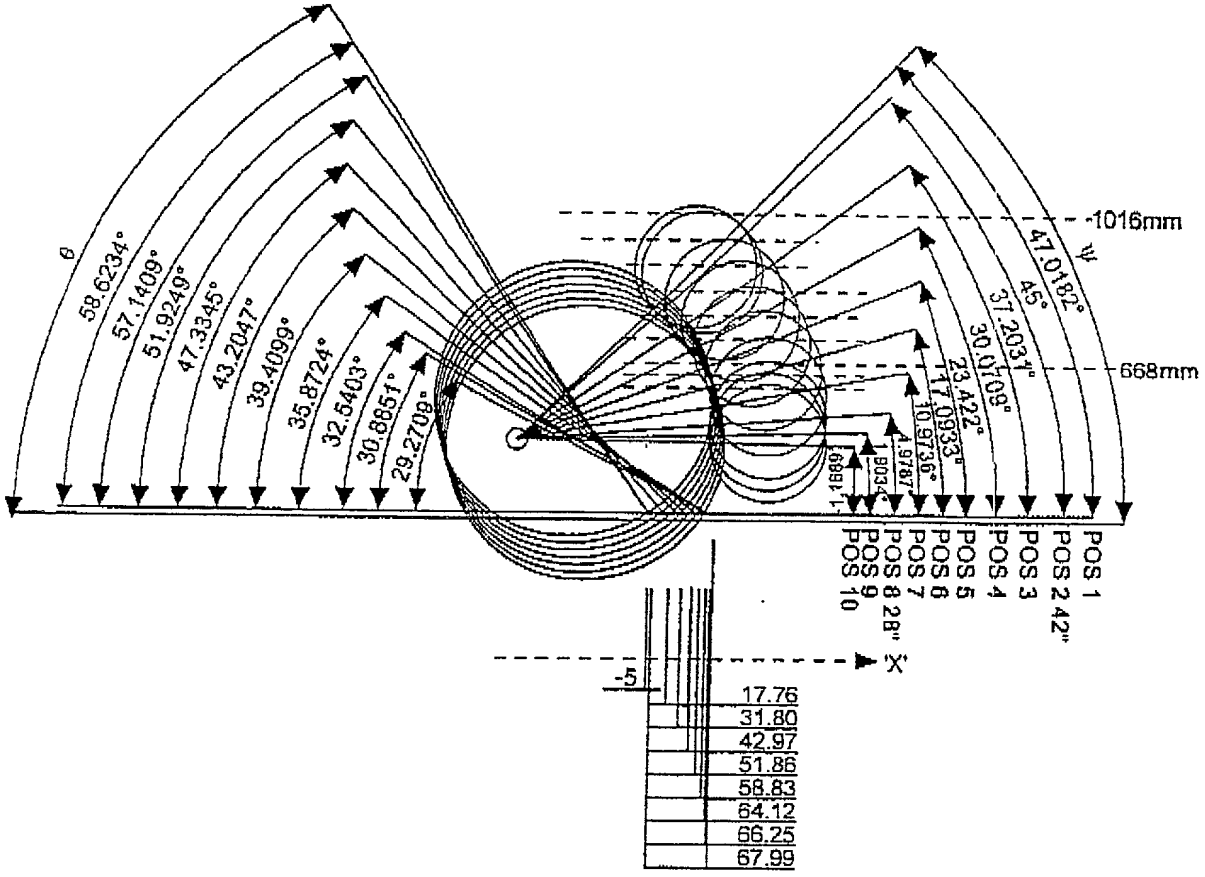

Fig. B

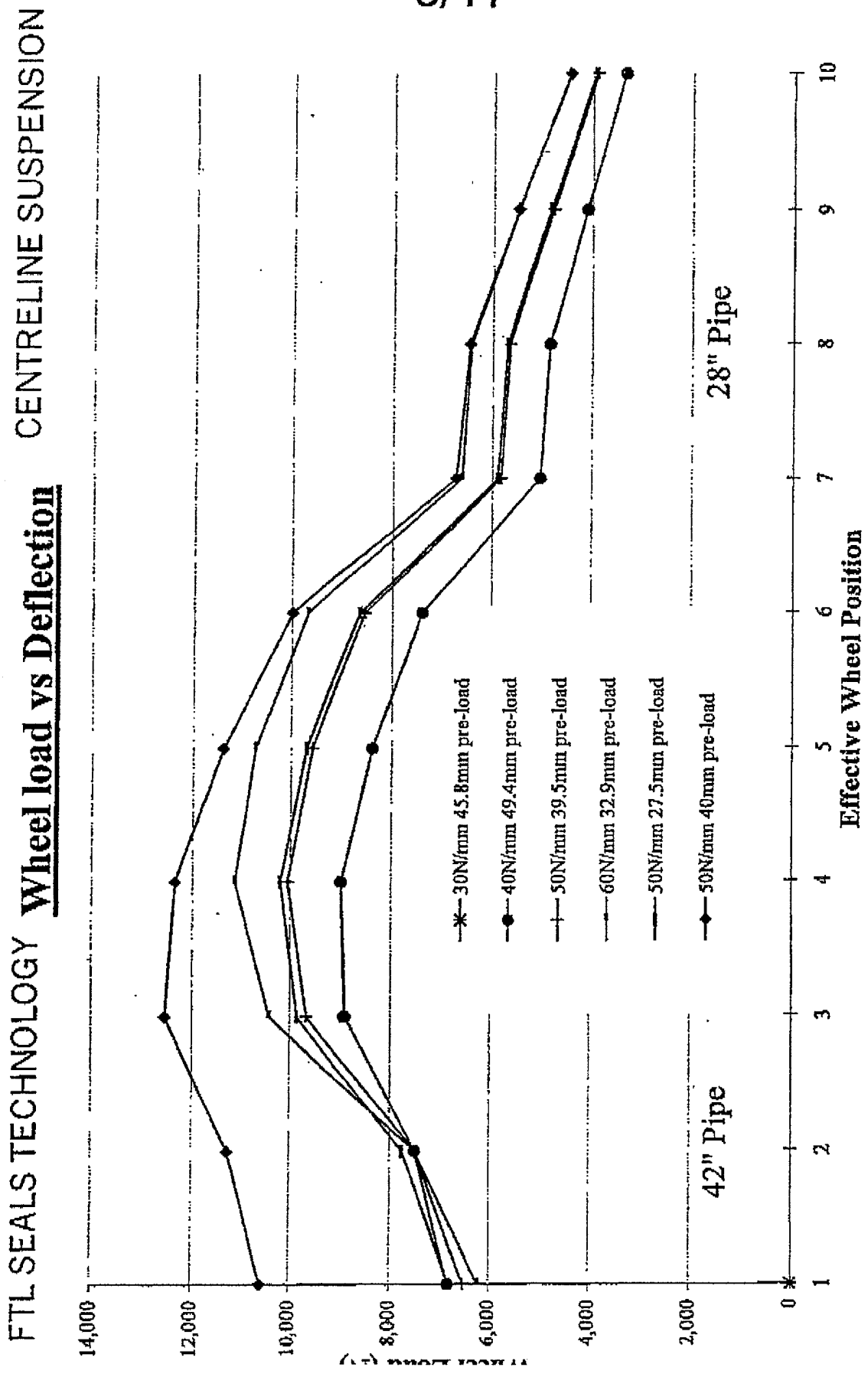
FTL SEALS TECHNOLOGY
Wheel load vs Deflection
CENTRELINE SUSPENSION
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1
2
3
4
5
6
7
8
9
10
Effective Wheel Position
30N/mm 45.8mm pre-load
40N/mm 49.4mm pre-load
50N/mm 39.5mm pre-load
60N/mm 32.9mm pre-load
50N/mm 27.5mm pre-load
50N/mm 40mm pre-load
42" Pipe
28" Pipe

Fig. C

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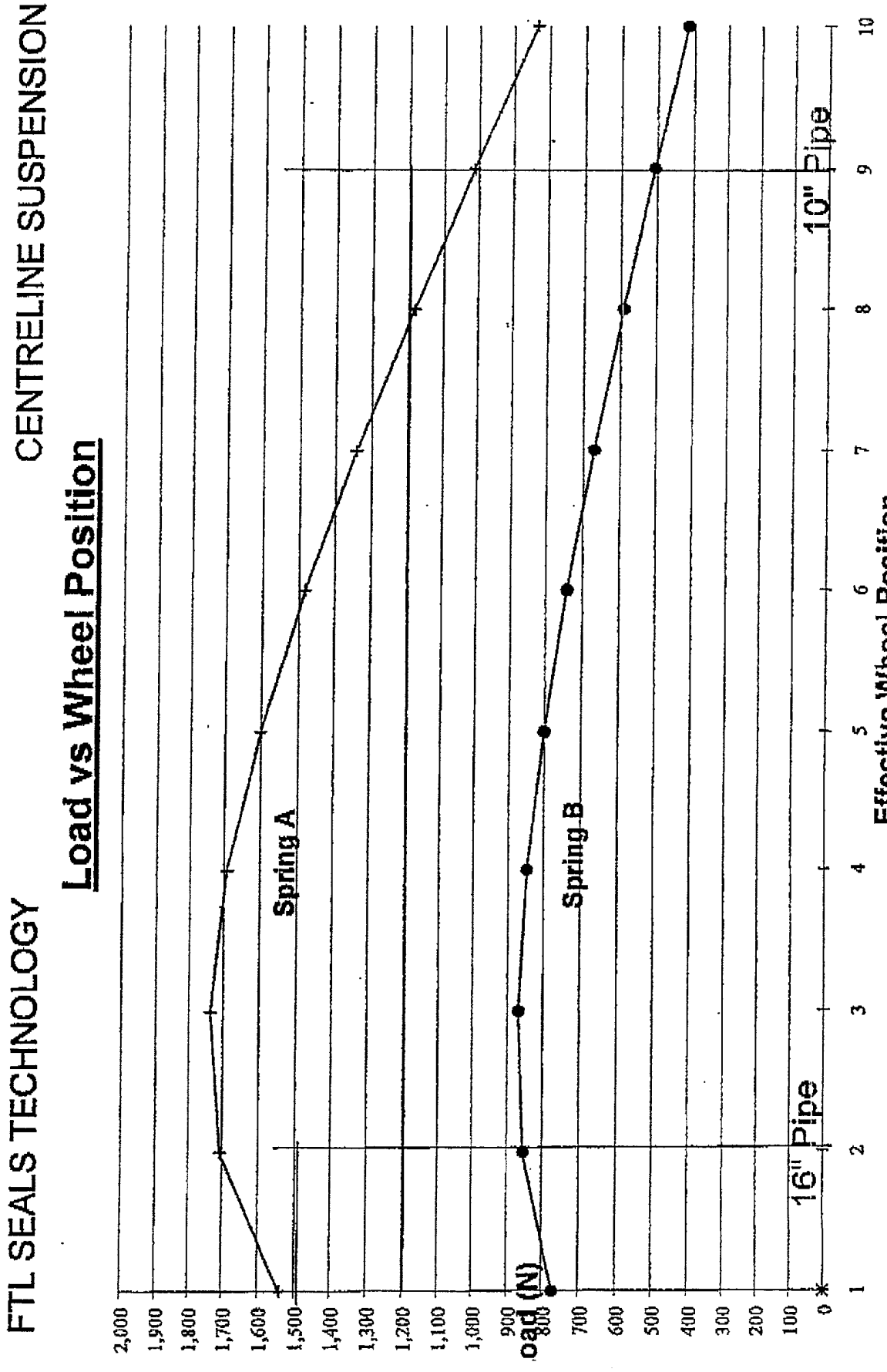

Fig. D

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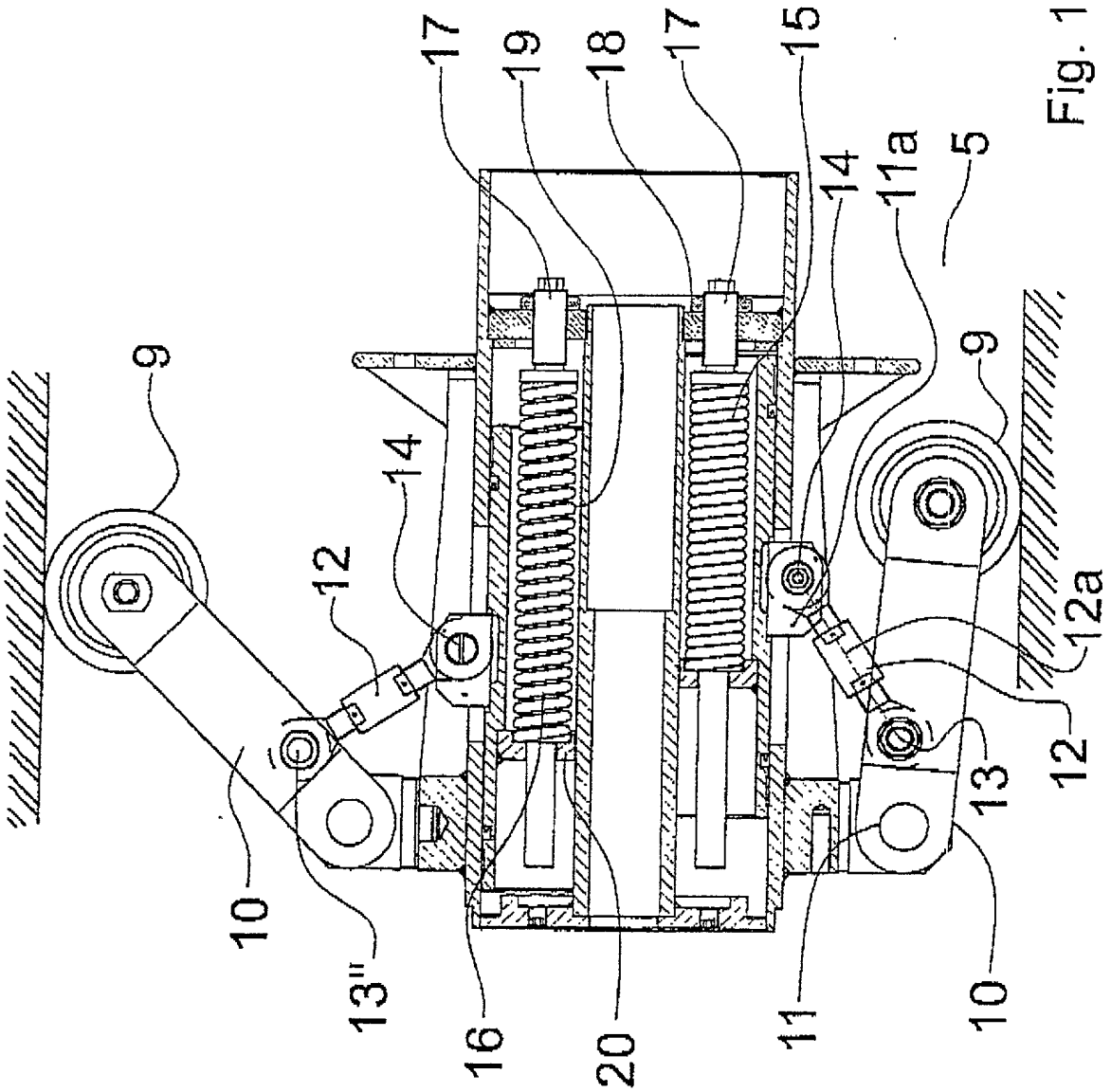

Fig. 1

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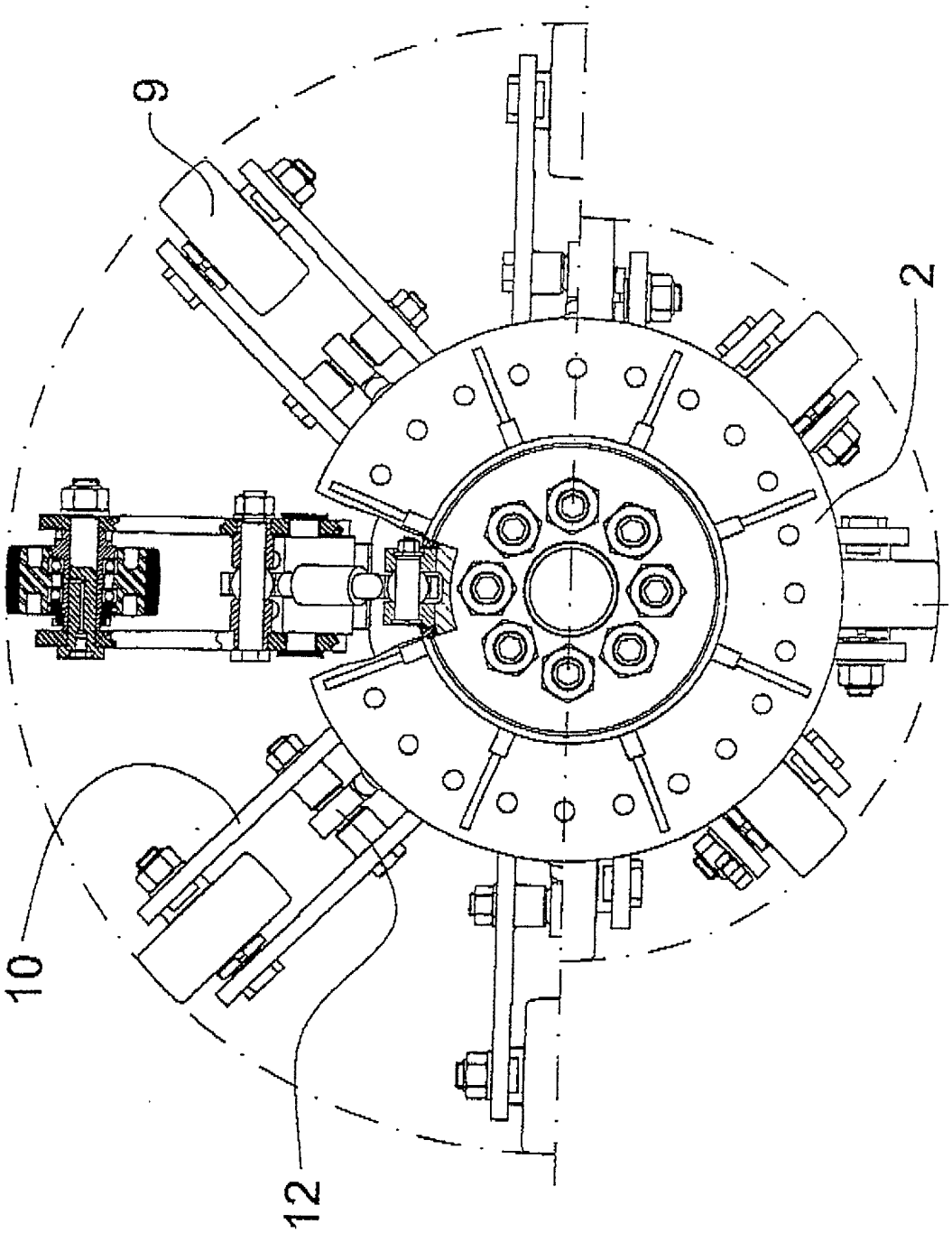

Fig. 2

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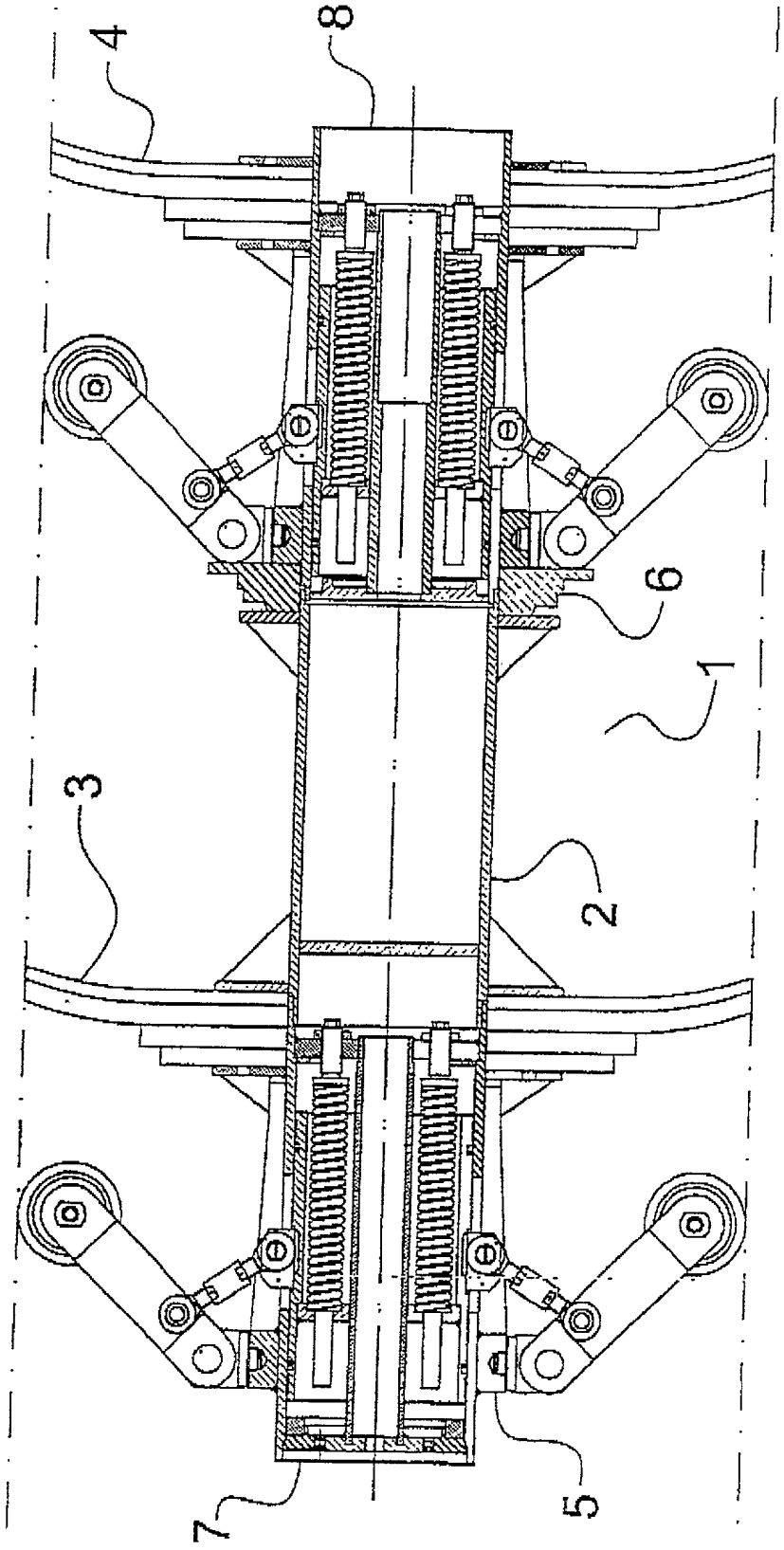

Fig. 3

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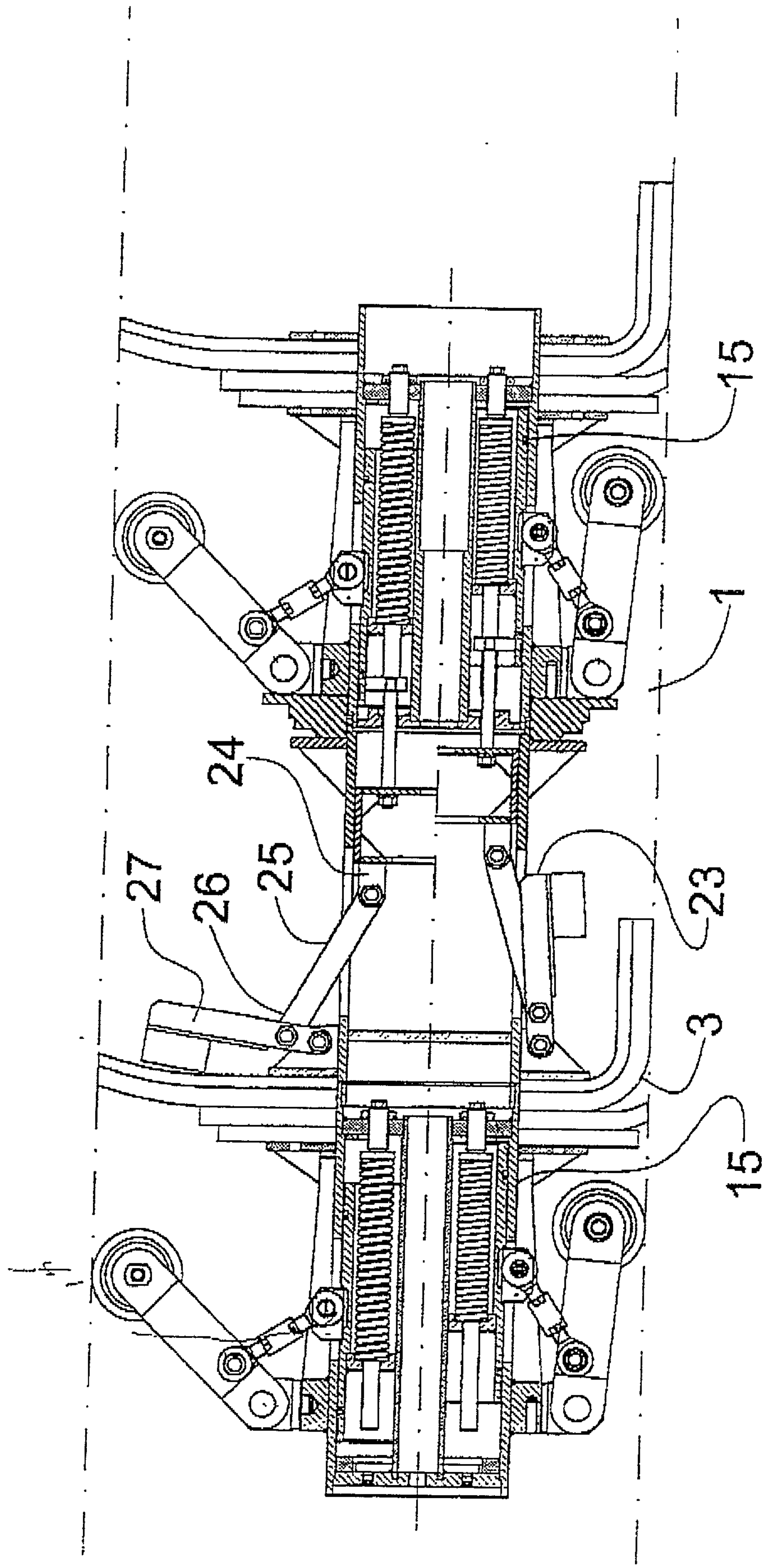

Fig. 4

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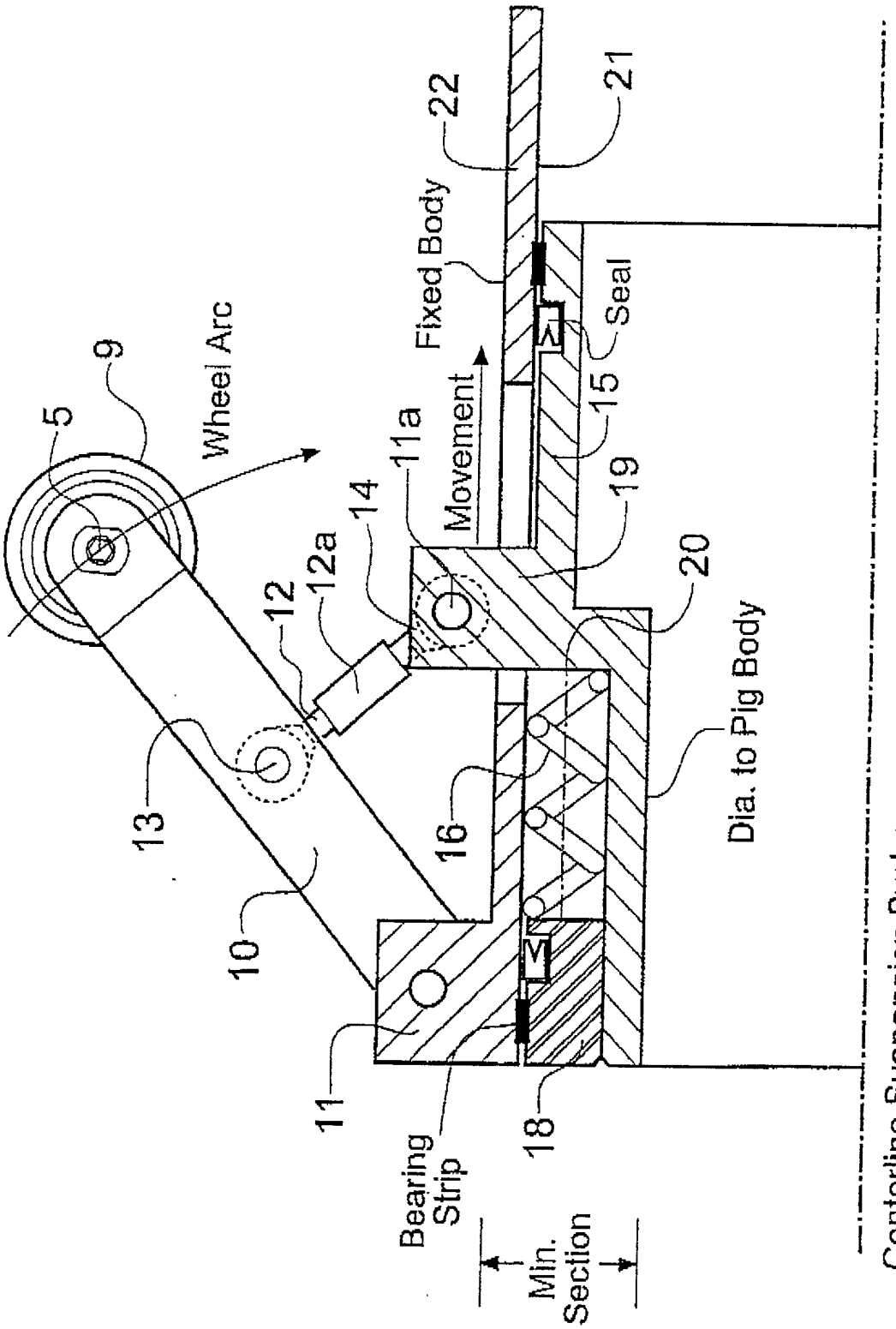

Fig. 5

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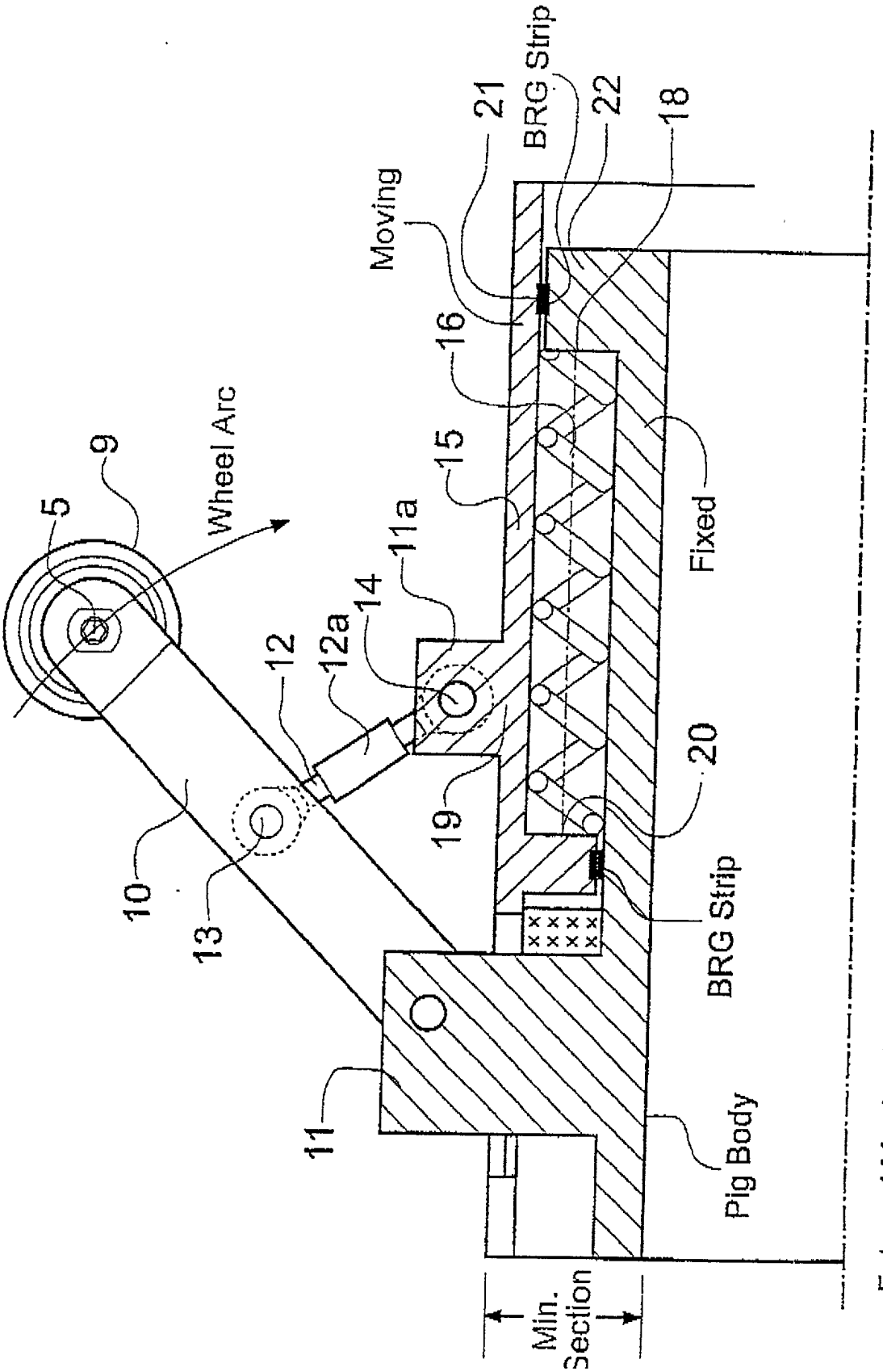

Fig. 6

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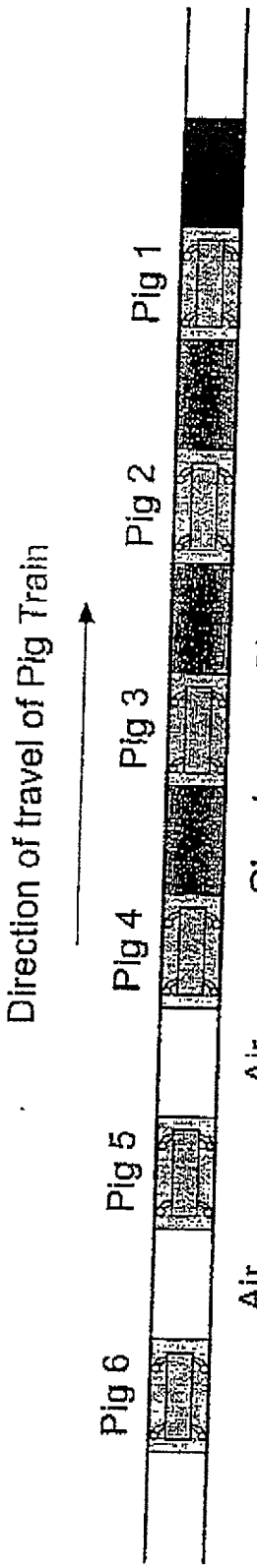

Fig. 7

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

Attorney Docket No. 9052-91

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled CENTRE LINE MULTIDIMENSIONAL SUSPENSION SYSTEM,

the specification of which

☐ is attached hereto

OR

☒ was filed on September 25, 2001 as United States Application No. 09/937,413 or PCT International Application Number and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56, including material information that became available between the filing date of the prior application and the National or PCT International filing date of the continuation-in-part application, if applicable.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or of any PCT International application having a filing date before that of the application on which priority is claimed.

PCT/GB00/01159	Great Britain	03/28/2000	☒ Yes ☐ No
Number	Country	MM/DD/YYYY Filed	Priority Claimed
9907145.8	Great Britain	03/29/1999	☒ Yes ☐ No
Number	Country	MM/DD/YYYY Filed	Priority Claimed
0001351.6	Great Britain	01/21/2000	☒ Yes ☐ No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)
Application Number(s)	Filing Date (MM/DD/YYYY)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or § 365(c) of any PCT international application designating the United States of America, listed below.

Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned
Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned
Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following registered attorney(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. I also appoint the following registered attorney(s) to represent me before all competent International Authorities in connection with

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